ASTME12.11.WG05 Flashing Lights

Report by Y. Ohno Jan. 21, 2002

Members:

Yoshi Ohno, NIST .. Chair
Carl Andersen, FHWA
Richard Austin, Gamma Scientific
Dennis Couzin, Avery Dennison
Mark A. Evans, Calcoast-ITL
Nick Hale, Consultant
Norbert Johnson, 3M
Alan Kravetz, Consultant
J Rennilson, Consultant
Prof. Schmidt-Clausen, Tech. Univ. Darmstadt

Mailing List:

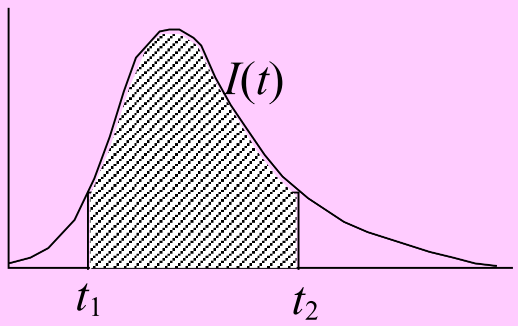
Anthony Martino, DuPont Central R&D
Francoise Viénot, France
Ian Tutt, UK

Methods for Effective Intensity Measurement

1. Allard (1876)
2. Blondel-Rey (1911)
3. Blondel-Rey-Douglas (1957)
4. Schmidt-Clausen (Form-Factor Method) (1971)

- Methods 3, 4 are extensions of 2, dealing with different ways of handling non-rectangular pulses.
- Methods 2, 3, 4 give equivalent results for rectangular pulses.
- All methods give the same results for very short pulses (e,g, 1 ms duration).
- Results vary significantly for various waveforms of pulses including a train of pulses.

Blondel-Rey (1911)



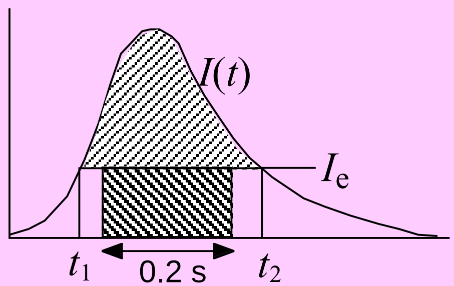
$$I_e = \frac{\int_{t_1}^{t_2} I(t)\mathrm{d}t}{a + (t_2 - t_1)}; \quad a = 0.2 \ s$$

t_1, t_2 are determined to satisfy

$$I_e = I(t_1) = I(t_2)$$

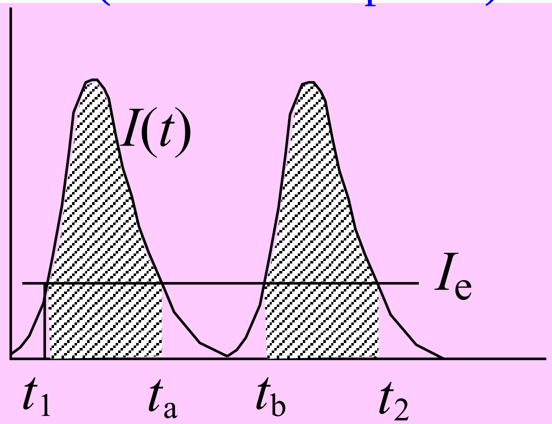
This is solved as

$$\int_{t_1}^{t_2} (I(t) - I_e)\mathrm{d}t = a \cdot I_e$$



Blondel-Rey-Douglas (1957)

(for a train of pulses)



$$I_e = \frac{\int_{t_1}^{t_a} I(t)\mathrm{d}t + \int_{t_b}^{t_2} I(t)\mathrm{d}t}{a + (t_2 - t_1)}$$

where $I_e = I(t_1) = I(t_2)$, a=0.2 s

It is solved as

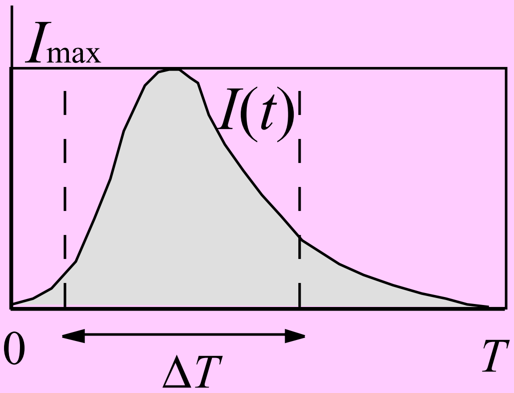
$$\int_{t_1}^{t_a} I(t)\mathrm{d}t + \int_{t_b}^{t_2} I(t)\mathrm{d}t = I(t_1)\{0.2 + (t_2 - t_1)\}$$

Then, $I_e = I(t_1)$.

Both cases need iterative solution.

Form Factor

Schmidt-Clausen(1971)



$$I_e = \frac{I_{max}}{1 + \frac{a}{F \cdot T}}; \quad F = \frac{\int_0^T I(t)\mathrm{d}t}{I_{max} \cdot T}$$

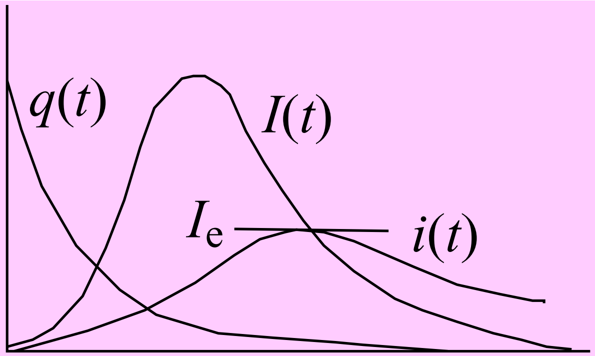
(a = 0.2 s)

This is transformed to:

$$I_e = \frac{\int_0^T I(t)\mathrm{d}t}{a + \Delta T}; \quad \Delta T = \frac{\int_0^T I(t)\mathrm{d}t}{I_{max}}$$

This can be realized by an analog circuit consisting of a current integrator and a peak-hold circuit.

Allard (1876)



Instantaneous effective intensity $i(t)$ is solved by the equation:

$$\frac{\mathrm{d}i}{\mathrm{d}t} = \frac{I(t) - i(t)}{a}; \quad a = 0.2\ s$$

I_e is the maximum of $i(t)$.

This is solved as

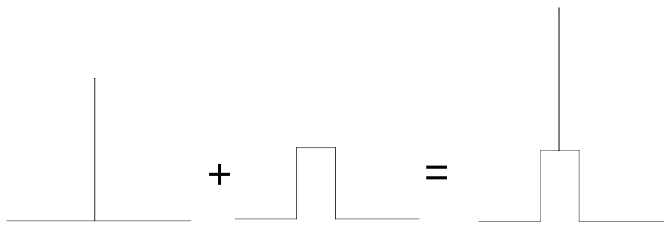
$$i(t) = I(t) * q(t); \quad q(t) = \frac{1}{a}\ \mathrm{e}^{-\frac{t}{a}}$$

$(*:\text{convolution})$

(1977 IALA paper)
(2001 D. Couzin)

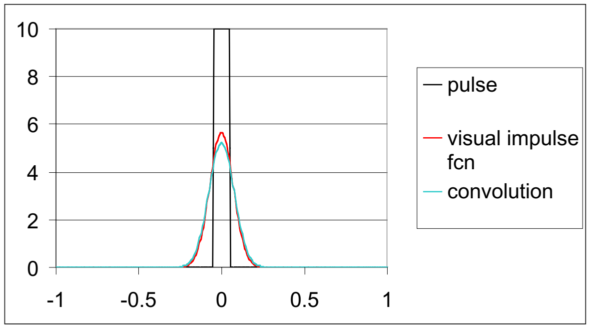
Dennis Couzin proposal (April 2000)

Couzin presented at CIE TC2-49 Meeting in April 2000 in London that Form Factor method clearly fails for the pulse as shown on the right.

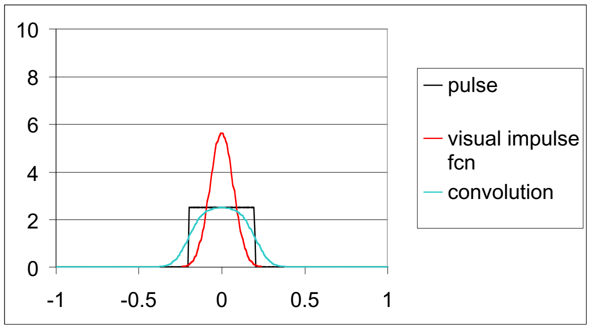


Couzin proposed that effective intensity can be measured accurately, without the problem above, based on the convolution of the flash pulse with a certain visual function (an example shown on the right). The effective intensity is the maximum of the convolution.

1



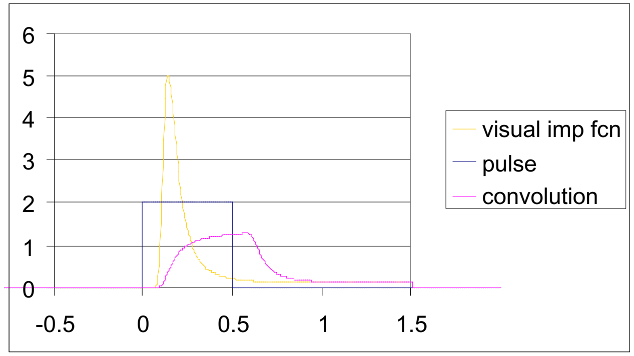
2



Dennis' proposal on Allard method (June 2001)

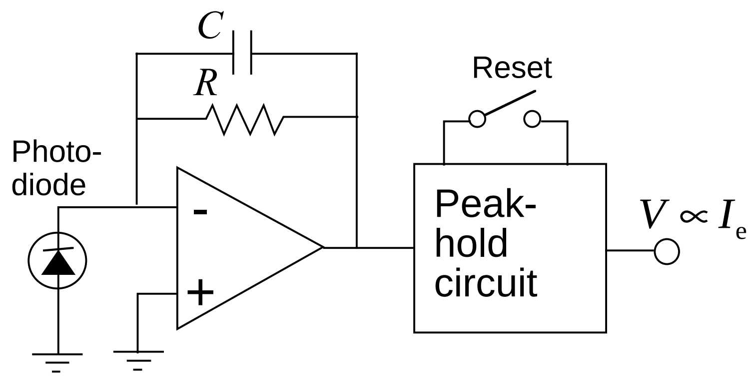
Couzin proposed at ASTM E12.11.05 meeting that Allard method (1876) is based on a convolution with an exponential visual impulse function, and is close to what he had proposed 124 years later.

Couzin suggested that the Allard method could be updated by adjusting this function to one that matched the later data for simple pulses. He showed a "beautified" version of Allard's $q(t)$ that resembled physiological functions and gave effective intensity values for rectangular pulses lower than Blondel-Rey.



Practical Aspects on Allard method

Allard method can be realized by an R-C filter circuit and a peak-hold circuit, which would be even simpler than the Form Factor method.



Calibration can be done simply by using a steady-light luminous intensity standard lamp (assuming the time constant *CR* is correct).

Analysis by Y. Ohno, Jan. 2002

Computation analysis was made using 10 different waveforms of pulses with duration from 0.001 s to 100 s.

Summary Results

1. For rectangular and trapezoidal pulses, Allard method (original) deviates significantly (up to 30 %) from Blondel-Rey-Douglas and Form Factor.
2. Form Factor method fails for “Dennis” pulse (a sharp noise added on the slow pulse).
3. Blondel-Rey-Douglas fails for modulated pulse at a certain duration and longer.
4. Both Form Factor and Blondel-Rey-Douglas fail for a train of short pulses.
5. No problem was found on Allard for any pulses, except for the problem 1.

Modified Allard Method
(Ohno & Couzin)

Observation:

- Blondel-Rey equation is believed to be accurate for rectangular pulses.
- Allard method seems to work well for any type of pulses, but it gives 20- 30 % higher values in the 0.1 to 1 s region.

Ohno proposed modifying the $q(t)$ function to a practical function, not necessarily a physiological function, that requires only simple circuitry and makes Allard results match Blondel-Rey for rectangular pulses.

The function q(t) is modified using two exponential functions:

$$q(t) = \frac{w_1}{a_1} e^{-\frac{t}{a_1}} + \frac{w_2}{a_2} e^{-\frac{t}{a_2}}$$

where

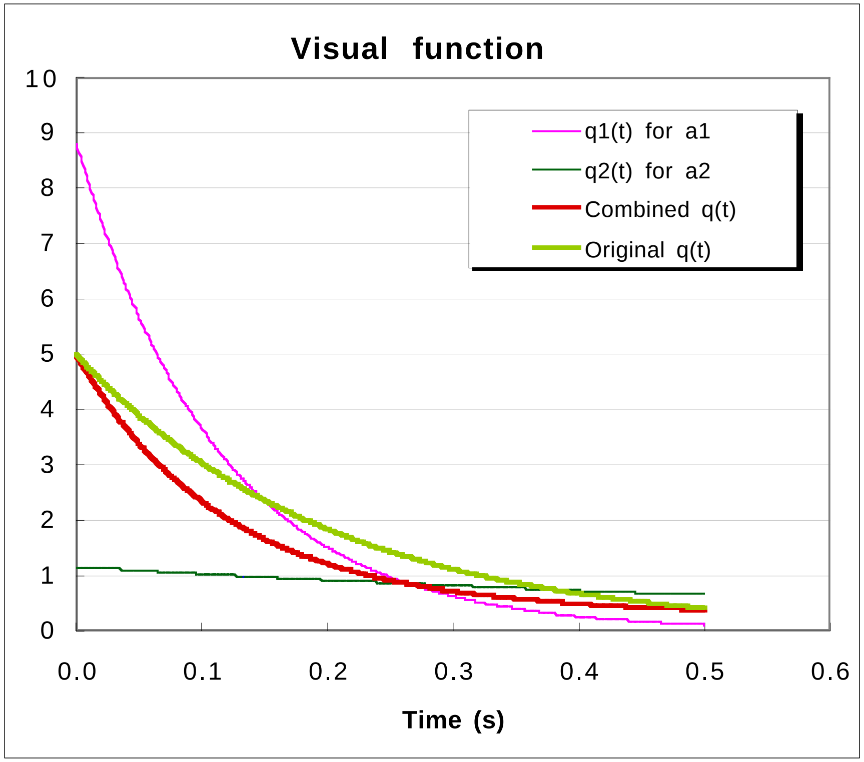
$$\frac{w_1}{a_1} + \frac{w_2}{a_2} = \frac{1}{a} \quad \text{and} \quad w_1 + w_2 = 1; \quad a = 0.2\ s$$

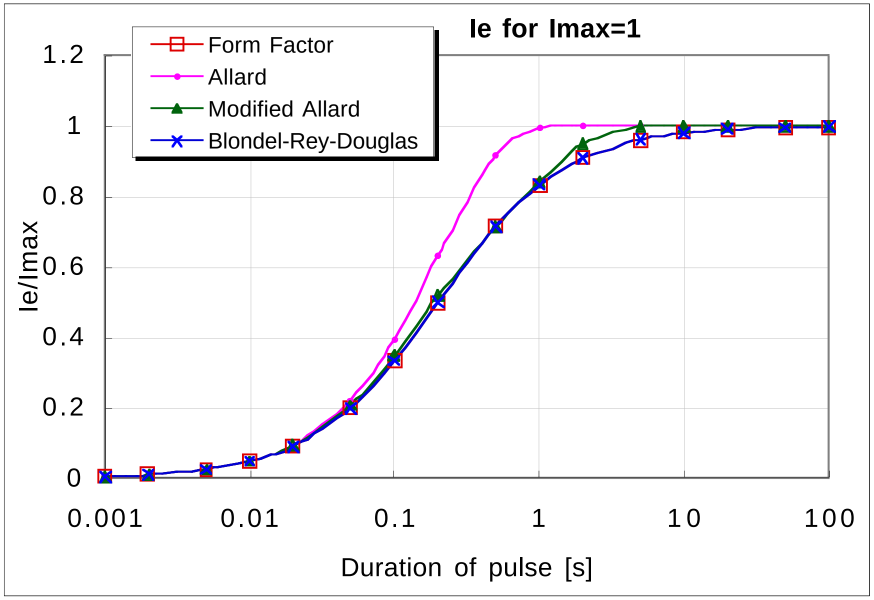
Modified Allard Method (Ohno & Couzin)

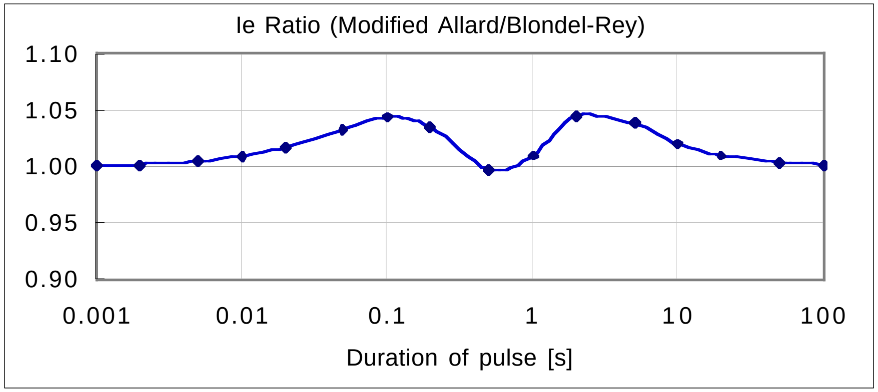
Rectangular pulse

Results (an example)

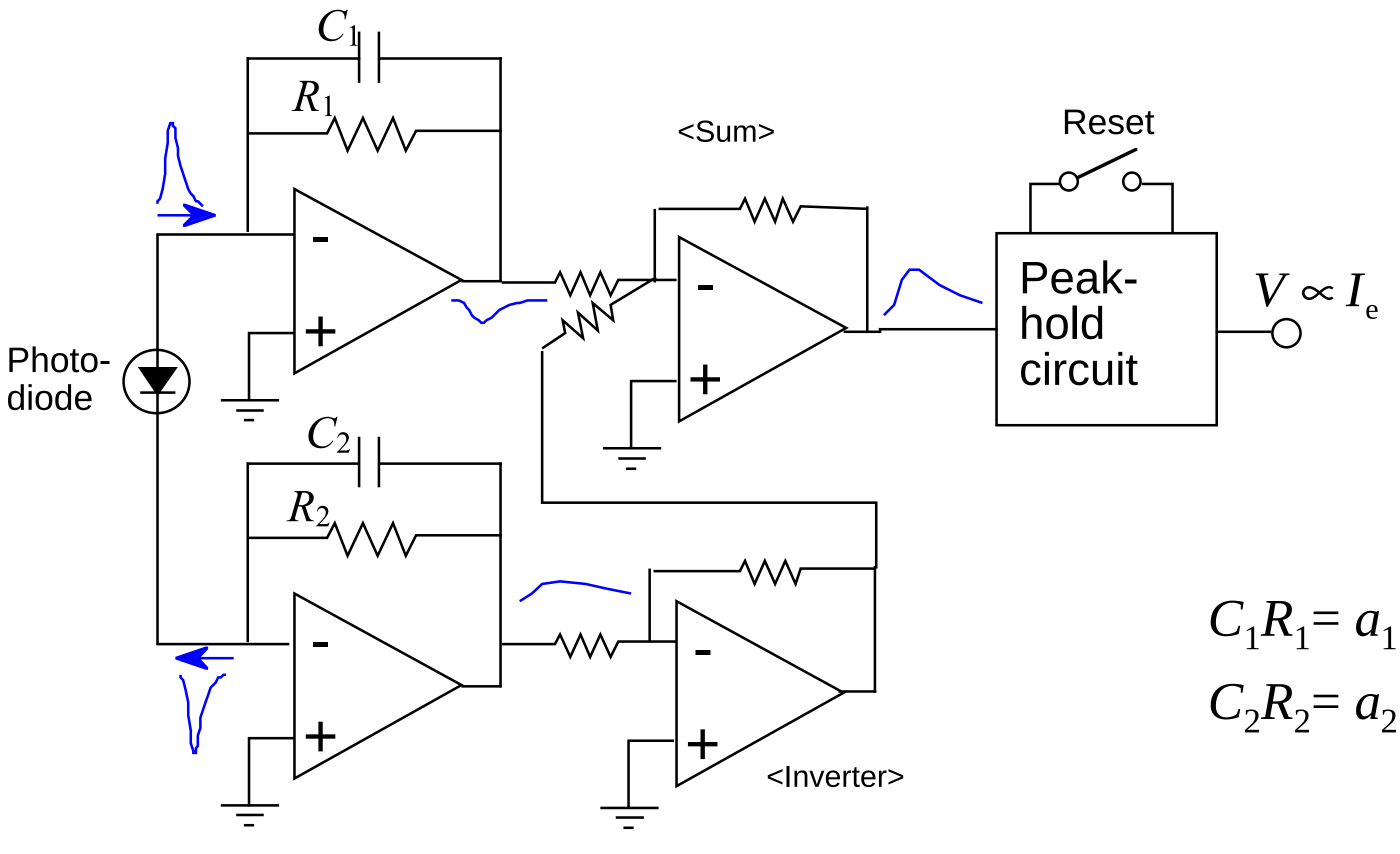
a_1=0.113, w_1=0.5
a_2=0.869, w_2=0.5







Circuit Example for Modified Allard Method



$$C_1R_1 = a_1$$

$$C_2R_2 = a_2$$

There may be even simpler ways to achieve this.

Modified Allard Method
(Ohno & Couzin)

Conclusions of the analysis

1. Modified Allard method (as optimized in the example presented) gives practically equivalent results (within 5 % difference) to Blondel-Rey (-Douglas) for single rectangular pulses.
2. It solves the problem of "Dennis" pulse.
3. It gives reasonable results for a train of pulses at any duration while Form Factor and Blondel-Rey-Douglas fail.
4. If necessary, it can be further optimized to fit experimental data that deviates from Blondel-Rey in the 0.1 to 1 s region.
5. It can be realized by simple analog circuits, which is an important requirement to produce portable photometers.